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OPTICAL EFFICIENCY MEASUREMENTS OF GEODSS ETS TELESCOPES FROM J--ETC(U)
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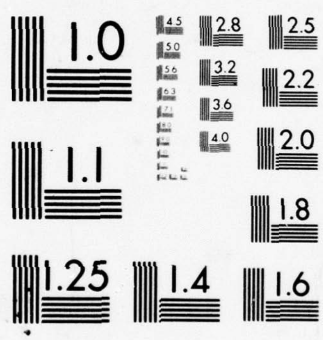

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OPTICAL EFFICIENCY MEASUREMENTS OF GEODSS ETS TELESCOPES FROM JULY 1976 TO DECEMBER 1977.

10 E. W. RORK

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PROJECT REPORT ETS-32

11 27 FEB[redacted]978

12 16p.

15 F19628-78-C-0002

16 2128

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LEXINGTON MASSACHUSETTS

ABSTRACT

Optical efficiency measurements are reported for five telescopes used with the GEODSS Experimental Test System, located at the White Sands Missile Range, New Mexico. The measurements were taken during the period July 1976 to December 1977, and the results indicate gradual decreases in the optical efficiencies of the telescopes with use. The decreases in optical efficiencies are due to dust which accumulated on the optical surfaces of the telescopes during ETS operations.

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I. INTRODUCTION

This note presents a record of optical efficiency measurements made on the GEODSS ETS telescopes during the past 1 1/2 years of ETS operations. The optical efficiency, or throughput, of the telescopes must be known in order to evaluate the performance of the complete ETS sensors and to assess losses in performance due to the accumulation of dirt and grime, etc., on the telescope optics.[1] The optical efficiency is not a reflection on the manufacturer's skills, but rather it is a function of the number of optical pieces and coatings we have specified and the dust collected on the surfaces during ETS operations.

II PRINCIPLE OF THE MEASUREMENTS

The measurement technique and equipment used are identical to those used for the first optical efficiency measurements reported for the ETS telescopes[1]. The optical efficiency, T, of a telescope is defined as:

$$T = \frac{\text{Total number of light quanta per second from the telescope comprising the image of a source.}}{\text{Total number of light quanta per second entering the telescope from the source.}} \quad (1)$$

The measurement technique is as follows: A small He-Ne laser (Metrologic ML-680, λ = 6328 Å) is pointed into the telescope such that the principal beam exits the telescope through the area of the focal plane normally occupied by the photosensitive surface of the TV camera. A radiometer (Tektronix Type J-16 Digital Photometer/Radiometer, #6502 Probe) is then used to measure the total power in watts in the laser beam going into and out of the telescope. The total power in the beam is proportional to the number of light quanta per second passing in the beam, and the ratio of the output power to the input power in the beam is the optical efficiency of the portion of the telescope aperture covered by the laser beam. If the covered area is representative of the entire aperture, the ratio is the optical efficiency T as defined by Equation 1. Thus, to determine the optical efficiency of a telescope by this technique, it is necessary to repeat the measurement sequence for each of several different locations in the aperture of the telescope to see if indeed the ratio remains constant over the aperture.

The repeatability of measurements taken using this technique is within 2%. The following possible sources of error were investigated in Reference 1,

and were found to be acceptably low:

1. Linearity of response of the photometer.
2. The effect of different optical path lengths in air between the input and output readings.
3. The effect of the laser beam diameter within the detector window.

The only source of difficulty in obtaining repeatable measurements has been variation with time in the intensity of the laser beam while the measurements were being taken. Leaving the laser on for 30 minutes prior to the measurements was found to reduce the variation to insignificant levels.

III. THE MEASUREMENTS

Table 1 presents the optical efficiencies of the GEODSS telescopes. Each entry is the result of at least 3 pairs of measurements of the incident and transmitted beam powers, measured alternately in sequence, at each of 3 different locations in the field of the telescope. All measurements at a single location in the field of a telescope were consistent to the two-digit capability of the Tektronix J-16 Photometer*, and variations of optical efficiency at different locations in the field were less than 2% of the reported value. In support of this finding, visual observation of exposed optical surfaces over a period of time indicates that the dust accumulates uniformly on them.

I note the following observation from Table 1;

1. The optics of the A 31-inch f/5 telescope have been in continuous use since July, 1976.** Since then, its efficiency has dropped from 0.73 to 0.60. The largest loss occurred between 10 Jan. 1977 and 27 April 1977, when it was discovered that the electronic air cleaner in Dome A was not functioning.

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*The Tektronix J-16 unit used (Ser. No. B020393) has a 2 1/2 digit readout, while the current model has a 3 1/2 digit readout.

**The optical system from Telescope A was returned for cleaning and rework in July, 1976 having been used since September, 1975. However, no optical efficiency measurements were performed when the optics were new. The clean optical system from A was returned in the B telescope.

TABLE I

OPTICAL EFFICIENCY MEASUREMENTS OF GEODSS ETS TELESCOPES FROM JULY, 1976 TO DECEMBER, 1977

Date of Measurement	A 31-Inch f/5	A 31-Inch f/2.87	A 14-Inch f/1.7	B 31-Inch f/5	B 14-Inch f/1.7
	Optical Efficiency T for Indicated GEODSS ETS Telescopes				
9 Jul 1976	0.73*	0.75*			
20 Sep 1976	0.74		0.56*		
30 Oct 1976	0.71				
10 Jan 1977	0.71				
8 Apr 1977				0.70	0.58
27 Apr 1977	0.64 Electronic Air Cleaner discovered inoperable; replaced immediately.				
1 Jun 1977			0.52 (Dirty corrector) 0.55 (After cleaning corrector)		
5 Sep 1977				0.69	
26 Sep 1977					0.58
5 Oct 1977			0.57 (New corrector)		
7 Oct 1977	0.60				
28 Dec 1977	0.60		0.55	0.67	0.57

*Measurements also reported in Reference 1.

Visual inspection of the telescope indicates that most of the dirt is on the exposed mirror and corrector lens, and hardly any dirt is on the secondary mirror which faces down.

Figure 1 presents a plot of the optical efficiency measurements of the A and B 31-inch telescopes as a function of time in use.

2. The B 31-inch f/5 telescope has been in continuous use since September, 1977. During that time its efficiency decreased only slightly, from 0.69 to 0.67. Its primary mirror is noticeably cleaner than the corresponding A telescope, which probably accounts for its 12% higher efficiency.

3. The effect of cleaning the Schmidt corrector plate of the A 14-inch telescope on 1 June 1977 is apparent. The dirty corrector had not been touched since its installation in the fall of 1975.

4. The drop in the optical efficiency of the B 14-inch telescope since its installation has been negligible. The telescope has been used very little because no TV camera has been available for it on a regular basis.

Table 2 presents the effective area in M^2 of the apertures of the ETS telescopes for each of the optical efficiency measurements of Table 1. The data presented in this way are convenient for computing sensor performance.

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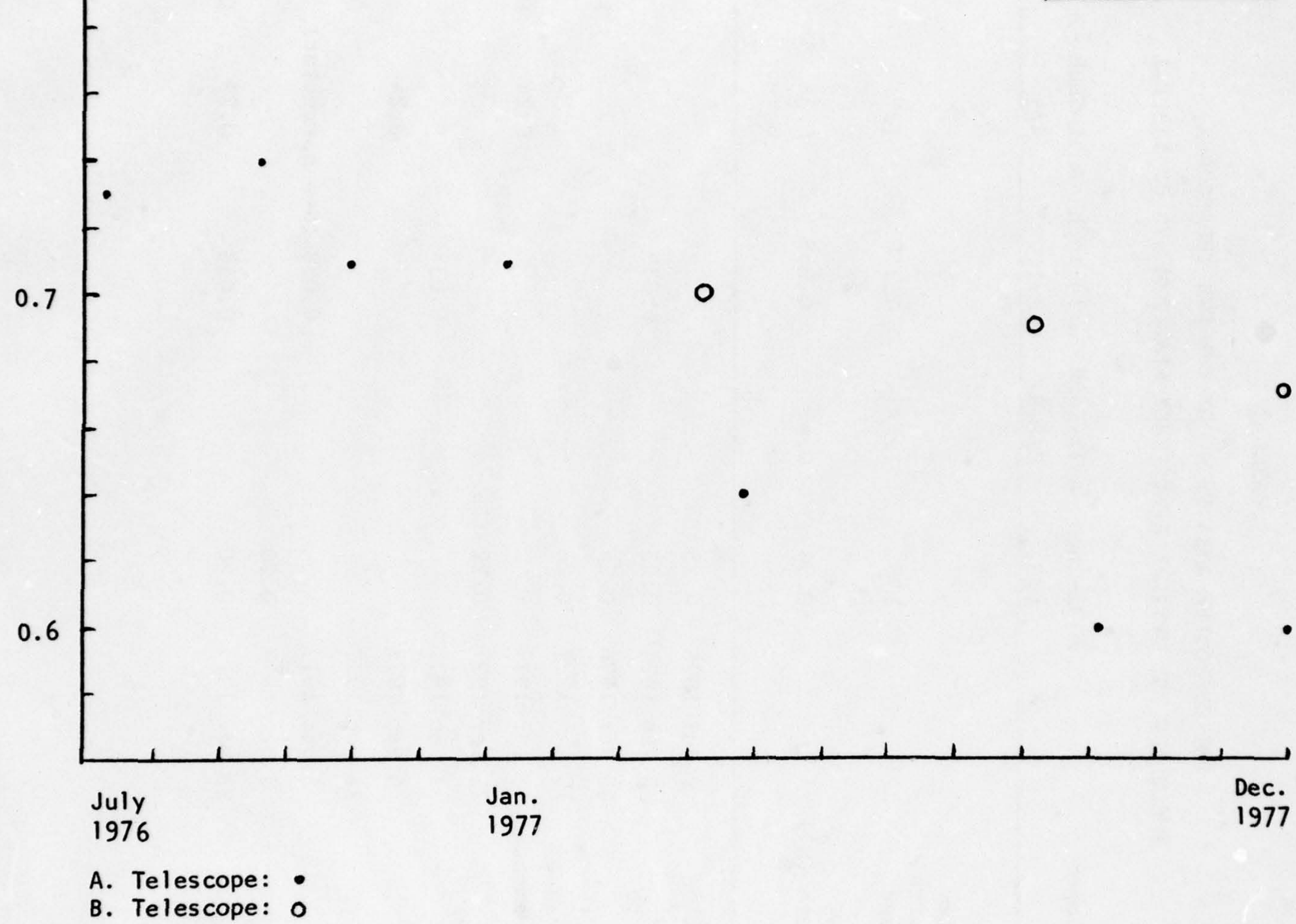

Fig. 1. The measured optical efficiency of the A and B 31-inch f/5 telescopes as a function of time.

TABLE 2

THE EFFECTIVE AREA IN M^2 OF THE ETS TELESCOPES, INCLUDING THE OPTICAL EFFICIENCY MEASUREMENTS OF TABLE 1

Telescope:		A 31-Inch f/5	A 31-Inch f/2.87	A 14-Inch f/1.7	B 31-Inch f/5	B 14-Inch f/1.7
Diameter of Central Blockage		17"	12"*	7.75"	17"	7.75"
Area of Aperture (M^2)		0.34	0.41	0.069	0.34	0.069
Effective Area of Aperture from Optical Efficiency Measurements on Indicated Dates: (M^2)	9 Jul 1976	0.25	0.31			
	20 Sep 1976	0.25		0.039		
	30 Oct 1976	0.24				
	10 Jan 1977	0.24				
	8 Apr 1977				0.24	0.040
	22 Apr 1977	0.22				
	1 Jun 1977			0.038		
	5 Sep 1977				0.24	
	26 Sep 1977					0.040
	5 Oct 1977			0.039 (new corrector)		
	7 Oct 1977	0.20				
	28 Dec 1977	0.20		0.038	0.23	0.039

* If a Westinghouse TV camera is used at the prime focus, the camera dimensions cause the blockage to be 16.5".

IV. CONCLUSIONS

A. During the past year and a half attempts were made to minimize dust accumulation on telescope optics when not in use by:

1. keeping the telescopes capped and vents sealed;
2. keeping the telescopes parked in a near horizontal position; and
3. maintaining a slight positive pressure in the domes using an electronically filtered air intake when the outside temperature was low.

As suggested in Reference 1, the dome air conditioners should be modified to permit a slight positive pressure to be maintained in the domes while cooling. At present, the air conditioners can't take in outside air when they are cooling or heating. If it is too difficult to modify them for this feature, then a separate filtered intake blower should be installed in the domes.

B. The A 31-inch primary mirror and corrector lens are approaching a condition where cleaning will be necessary. It is reasonable to infer that most of the dirt accumulated during operations, and not during storage. If most of the dirt accumulated during storage, the secondary mirror would show as much or nearly as much dirt (it is partially shrouded by the sky baffle) as the primary and corrector, since the telescope was stored in a near horizontal position. The secondary mirror appears very clean.

C. Before the A 31-inch primary mirror is cleaned, a comparison of the optical performance of the A and B telescopes should be made to see if scattering by dust is a serious problem. Since the primary mirror is exposed to considerably more sky area than that subtended by the FOV angle,

skylight from the entire exposed area of sky may be scattered from dust on the primary onto the photocathode. Such an experiment would help to determine how much dust is tolerable for GEODSS operations. A good time for such an experiment is during the time of a full moon.

Possibly a technique may be devised to measure the intensity of scattered light from a portion of the primary mirror illuminated by the laser beam. One method of measuring the intensity of scattered light in a direction different from the principal ray would be to place an image of the illuminated portion of the primary mirror on a radiometer, such as the Tektronix J-16 radiometer, by the use of an imaging lens in the light path.

D. Optical efficiency measurements should be made on a regular basis, perhaps once per month. A jig has been constructed for each dome which makes it easy and safe for one person to remove a TV camera from a telescope and replace it as required for the measurements. Previously, the job required 3 persons and considerable exertion.

ACKNOWLEDGMENTS

The author thanks Robert Irelan for helping to make some of the measurements reported herein and for constructing the jigs to facilitate safe and easy removal and replacement of the TV cameras on the telescopes. The author also thanks Ms. Rene Weiss for typing and proofreading the manuscript.

REFERENCES

1. E. W. Rork, "Optical Efficiency Measurements of GEODSS Telescopes," Project Report ETS-5, Lincoln Laboratory, M.I.T. (8 October 1976), DDC AD-A033945.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESD-TR-78-26	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Optical Efficiency Measurements of GEODSS ETS Telescopes from July 1976 to December 1977		5. TYPE OF REPORT & PERIOD COVERED Project Report 6. PERFORMING ORG. REPORT NUMBER Project Report ETS-32
7. AUTHOR(s) Eugene W. Rork		8. CONTRACT OR GRANT NUMBER(s) F19628-78-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lincoln Laboratory, M.I.T. P.O. Box 73 Lexington, MA 02173		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element No. 63428F Project No. 2128
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command, USAF Andrews AFB Washington, DC 20331		12. REPORT DATE 27 February 1978 13. NUMBER OF PAGES 18
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Electronic Systems Division Hanscom AFB Bedford, MA 01731		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

optical efficiency measurements	ETS	optical surfaces
GEODSS	dust control	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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